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'Reservoirs' and 'Repertoires': Epistemological and Discursive Complexities in Multidisciplinary Engineering Practice

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Abstract

At the heart of the redesign of Higher Education qualifications in South Africa lies the issue of increasing evidence of student difficulties in integrating different forms of knowledge. This article proposes that in order to design curricula and pedagogy which better prepare our graduates for legitimate participation in the world of work, we need to understand what that participation might look like. Using a Bernsteinian (Bernstein 1996, 2000) conceptual framework, a research study was conducted which entailed mapping the knowledge integration practices of final year multidisciplinary engineering diploma students in a situated learning environment. The intention of the research was to illuminate the nature of and relationship between the different forms of knowledge evident in actual practice. The concurrent analysis of discursive practices representing complex knowledge integration reveals that in addition to forms of meaning-making associated with traditional engineering disciplines, successful practice is dependent on the ability to draw on a range of oral and written individual '*repertoires'*, as well as those of a collective '*reservoir*' that stretches beyond the academy: the invisible community of users on the Internet. The complex praxis and concomitant discourses described in this article suggest we need to see *integration* of knowledge as more than that of language and content, or concept and context, rather as a system of 'collaboration' at multiple levels.

Introduction

'Collaboration is the stuff of growth'. Sir Ken Robinson (2010)

A practice that has emerged across faculties in Higher Education (HE) institutions in South Africa is that of Academic Literacy/language practitioners collaborating with disciplinary specialists in various forms to enable the development of the necessary discursive practices required for an academic qualification in a particular discipline. A key insight required for successful collaboration between academics is how knowledge is 'produced within their own disciplines, and the implications of this for teaching and learning' (Jacobs 2007: 69). However, discussions around collaboration between experts with knowledge of their disciplines and those with native language and communication structures expertise (Paretti 2011) have not sufficiently taken into account the rapid emergence of multidisciplinary 'regions' (Bernstein 2000) in which a number of disciplines along with their associated discursive and applied practices meet to form an entirely new 'region'.

In such combinations of pure, applied and integrated disciplines, the notion of collaboration has many facets. On the one hand, multidisciplinary curricula often manifest as a collection of different subjects, taught by individual specialists with particular disciplinary expertise, and who may or may not collaborate to facilitate integration of the required knowledge areas peculiar to the new 'region'. On the other hand, the notion of collaboration is also that which underpins what it is the student is required to do: integrate significantly different forms of disciplinary knowledge in particular contexts of application. Successful integration depends on a conceptual grasp of how the different forms of knowledge 'collaborate', as it were, in a particular context. The contention in this paper is that a deeper understanding is required of the epistemological and discursive complexities involved in multidisciplinary engineering practice. Practice in regions dependent on student engagement with rapidly evolving application-specific technologies has seen a shift towards increasing exposure to a range of texts, sites of knowledge generation, and discursive practices that lie beyond the control of academic gatekeepers. This shift has further implications for the very notion of collaboration within an academic environment.

The research site is the third year of Work-Integrated Learning (WIL) on a Mechatronics diploma programme at a South African University of Technology. WIL is a collective term for a range of theory-practice integration opportunities, such as situated learning, experiential training or workplace-based learning, which can take place in the university, laboratories or industry. Mechatronics Engineering is the computer-based control of electro-mechanical systems, and the curriculum is constructed by drawing from the pure disciplines (such as physics and mathematics), 'regions' such as Mechanical, Electrical and Computer Engineering, and subject areas created to allow for the integration and application of knowledge specific to the emerging region (such as Computer-Aided Manufacturing). Each of these curricular elements (taught by individual specialists with particular epistemic orientations) implies fundamentally different knowledge structures, acquisition processes and discursive practices. Collectively, however, their synthesis represents an emerging region for which there is, as yet, no defined 'semiotic domain' or 'affinity group' (Gee 2002).[1] Observation of markedly differential student performance on the programme initially led to an investigation that focused on language, multilingualism (Cummins 1996) and discourses (Gee 1996), given the multilingual and multicultural student base. However, increasing evidence beyond the research site of students' difficulties in integrating multidisciplinary knowledge in this particular region (Bailey McEwan 2009, Bishop 2002 and Shooter and McNeil 2002) supported the hypothesis that curriculum designers may have underestimated the complexity in the nature of the knowledge itself.

The aim of this article is to illuminate the epistemological and discursive complexities of student engagement in practices that pre-empt those required in the world of work. The article draws on a methodologically pluralist research project which saw the mapping and description of the sequence of different forms of knowledge as students designed and constructed a controlled electro-mechanical system (Wolff and Luckett 2012). Against a Bernsteinian (Bernstein 1996, 2000) conceptual framework describing the underlying knowledge structures, and the work of Karl Maton (2009) for analysis of the knowledge integration process, a map of 'complex praxis' (Wolff and Luckett 2012) over time emerges. The nature of this praxis implies the need for broadening our understanding not only of the various discursive spaces we need to acknowledge as fundamental to the integration of knowledge, but of the switching required between the different forms of discursive and knowledge practices in particular contexts.

The practices described in this paper are situated in a student-centred and constructivist learning paradigm, within an environment characterised by a notion of collaboration that goes beyond that of content and language lecturers. Given the relative freedom of a self-regulated and peer learning environment, and collaborating on a complex design problem, analysis of the student practices (by way of reflective texts, observations, and interviews) reveals that they draw on a range of individual 'repertoires', sets 'of strategies [...] and their analogic potential for contextual transfer' (Bernstein 1996: 158), which collectively contribute to a growing 'reservoir' of strategies for this emerging community of practice. That this reservoir stretches beyond the walls of the academy, and has as its platform the most powerful of technologies, the Internet, presents a particular set of challenges for HE. It calls into question

[1]At the time of the research there was only one multidisciplinary academic on the programme.

the notion of *which* discursive practices are appropriate to enable complex knowledge integration in twenty-first century engineering curricula designed to meet labour-market requirements for professional qualifications. It also demands a reconceptualisation of the collective role of academics in collaborating to ensure access to the required practices.

The article sets out to contextualise the analysis of knowledge integration practice by establishing the broader theoretical framework of Bernstein's knowledge structures, and briefly summarising the methodology for arriving at a graphic depiction of complex knowledge integration process over time. The focus of the paper is one particular instance of the knowledge integration process which demonstrates the shifting between fundamentally different forms of knowledge and their relevant discursive practices. This micro examination hopes to reveal the disjuncture between traditional approaches to academic discourse induction and the discursive practices required for real 'complex praxis'.

Conceptual Framework

'Bernstein's work represents one of the most sustained and powerful attempts to investigate significant issues in the sociology of education' and provides 'a systematic analysis of codes, pedagogic discourse and practice and their relationship to symbolic control and identity' (Sadovnik 2001: 696). The theoretical focus of this article is Bernstein's characterisation of two discourses: 'Vertical discourse takes the form of a coherent, explicit and systematically principled structure' (1996: 157) (such as in education), whereas horizontal discourse is context-specific and -dependent everyday knowledge embedded in on-going practices.

Horizontal discourse: reservoirs and repertoires

Horizontal discourse is used to refer to everyday knowledge, which is segmentally organised and contradictory across contexts (Bernstein 1996). Bernstein cites such examples as using the lavatory and tying one's shoelaces, in which practices may differ according to how the 'culture segments and specialises activities and practices' (1996:157). These practices are segmental in that they are all significant, but do not necessarily build on each other to achieve an abstract principle (as in the case of vertical discourse). Individuals acquire these practices, for the most part, through modelling by 'the family, peer group or local community' (1996:159). Bernstein refers to the acquisition of horizontal discourse practices as the development of a 'set of strategies' or 'repertoires' through which to function in different social or practical contexts. The term 'reservoir' refers to the total sets of repertoires in a particular community. The less isolated a community is, the greater the opportunity for the 'circulation of strategies, of procedures and their *exchange*' (Bernstein 2000: 158) (original emphasis). The consequence of massification in education, increasing cultural diversity, and the ubiquitous Internet is such that both access and contribution to this collective reservoir, effectively speaking, means the exponential exchange of sets of strategies with regard to everyday knowledge.

Bernstein's description of the acquisition of horizontal discourse could be applicable to the non-disciplinary[2] discourse practices with which students in engineering in HE are expected to engage. Subjects such as Communication Skills and Professional Practice, common to vocational/professional curricula, are precisely about the development of oral and written repertoires that enable the individual to engage meaningfully with others in particular professional contexts. This notion of 'repertoire' may be what Gee refers to as 'stored 'lore' about a practice in a domain' (2008: 144). Each 'domain' has a 'design grammar', a set of domain-specific communication principles, the mastery of which grows through 'membership in its associated affinity group' (2008: 141). In other words, through 'modelling' in much the same way as Bernstein describes the development of a 'repertoire'.

[2]I am differentiating in this article between the epistemological foundations of a specific region, namely Mechatronics, and a range of practices that are not specific to the region. The term 'non-disciplinary' refers to the latter, although many of these may be 'disciplinary' in their own right.

The lines between the two discourses (everyday knowledge and formal knowledge) become blurred when, as Bernstein suggests, 'segments of *Horizontal discourse* become resources to facilitate access to *Vertical discourse*' (Bernstein 2000: 169). I would argue that the genre approach to teaching generic communication practices (such as report writing, correspondence, and interview processes) demonstrates the pedagogic 'recontextualisation' (Bernstein 2000) of acts of communication based on repeated 'every day' horizontal discourse interactions into formalised (vertical) discourse as a result of the recognition of common structural principles and certain conventions (shaped by human contexts). On the other hand, the pedagogic inclusion of horizontal discourse segments is also designed to improve 'the student's ability to deal with issues arising in the students' everyday world', such as that of 'work' (Bernstein 2000). This demonstrates the 'employability' thrust of professional qualifications; the imperative to equip students to be able to engage in real world practices.

Vertical discourse: hierarchical and horizontal knowledge structures

Whereas the relationship, in educational environments, between the two discourses has become more porous, Vertical Discourse (formal knowledge) has two distinct types of knowledge structures, and the distinction between them is crucial to understanding differences in acquisition and application, and hence integration. The natural sciences are characterised by their hierarchical structure. This is a form of knowledge which 'attempts to create very general propositions and theories, which integrate knowledge at lower levels' (Bernstein 2000: 161). This form of knowledge becomes increasingly abstract. The concept of force in physics, for example, is reduced to an abstract formulation (F=ma) which has subsumed the concepts of number, matter, mass, time, motion, and acceleration, and the various relationships between these concepts. Conceptually, hierarchically structured knowledge is highly dependent on sequencing and subsumptive progression, and builds over a long period of time (beginning with concepts established in early childhood). The abstraction cannot fully be grasped without an understanding of the elements which have been subsumed. Furthermore, discursively, this abstraction presents itself in increasingly reduced form.

In contrast, horizontally-structured formal knowledge consists 'of a series of specialised languages with specialised modes of interrogation and criteria for the construction and circulation of texts' (Bernstein 2000: 161). Each school of thought in philosophy, for example, each language, or each computer programming language, has its own criteria for legitimate texts, its own principles as it were. In the case of programming languages, different 'languages' are constantly emerging, borrowing linguistic elements like syntax or semiotics from each other, and quickly face obsolescence. This means that unlike hierarchically structured knowledge, which is highly dependent on sequence and reductive abstraction, acquiring horizontally-structured knowledge entails the independent learning of 'masses of particulars' (Muller 2008: 15), not necessarily sequentially, and more often than not in specific and multiple contexts. This has implications not only for the curricular and pedagogic allocation of time required to acquire these different forms of knowledge, but also for the nature of the associated discursive practices. Hierarchically structured knowledge is reductive; horizontally structured knowledge is proliferative (Young and Muller 2007).

Classification

Bernstein proposed a further distinction between types of knowledge, mainly with regard to vertical discourse: the degree of classification. The stronger the classification, the more unique a category's identity, voice, and 'specialised rules of internal relations' (Bernstein 2000: 7). This is most evident in the natural and mathematical sciences, induction into which 'takes the form of a long initiation' (1975: 82), and hence affords these disciplines high status. Bernstein termed these disciplines 'singulars'. Weak classification is particularly evident in the 'regionalisation of knowledge': the recontextualisation of singulars into regions, such as medicine and engineering (2000: 9).

In his earlier work, Bernstein describes a curriculum as a 'collection type' (1975: 80) when the 'high status contents stand in closed relation to each other'; in other words, a collection of strongly classified separate subject types. An 'integrated type' curriculum is one in which 'previously insulated subjects' are subordinate to a 'relational idea' (1975: 93). Typically, Engineering curricula start out as a collection type, with strongly classified traditional science and mathematics subjects. Over time, and dependent on the curriculum design, 'engineering' subjects specific to a particular specialisation are added. The first year of the Mechatronics curriculum in this research would be described as a collection type, with strong fundamentals in physics-based 'mechanics', 'electrical' and mathematics. By the second year, the curriculum shifts to a more integrated type with the addition of applied subjects such as the weakly classified 'Computer Aided Design' and 'Networking' (both of which demonstrate the blurring of the boundaries between the disciplines of logic, physics and mathematics).

What is important here is to understand that each of these types of knowledge not only needs to be learned in a different way, but takes on fundamentally different forms of representation: the alpha-numeric, graphic representations of mathematics are different from the alpha-numeric, schematic and relational ladder-logic diagrams peculiar to programming, for example. Similarly, the structurally representative diagrams of mechanical engineering differ from relational, symbolic circuit diagrams of electrical engineering, despite both fields sharing a physics and mathematics base. Whilst distinguishing between the different types of knowledge structure and classification helps to analyse a curriculum and develop appropriate pedagogic approaches, on their own these subjects do not constitute the 'region' of Mechatronics.

Original Research Project Context and Analysis

Mechatronics engineering is defined as 'the concurrent design, manufacture, integration and maintenance of controlled dynamic electro-mechanical systems' (MEFSA 2011), and the assumption in the curriculum is that the 'collection' of subjects characterising each descriptor together constitute the whole. Student performance at the research site (and beyond) consistently demonstrates that though the student may excel in the different subjects, it is in the design and project subjects in the final year that the inability to integrate the required forms of knowledge becomes evident. This observation served as impetus for the original research project: an analysis of the knowledge integration pattern of one particular project group in order to understand the nature of and relationship between the different knowledge forms.

In the first half of the final year, prior to a semester of Workplace Learning in industry, Mechatronics diploma students work on campus in a simulated professional environment, resembling an automated, high-tech factory. They are entirely responsible for their own learning and schedule, expected to teach themselves a range of new technologies, and complete a 'design and manufacturing' project in a group. Each student has his/her own laptop, all resources are electronically available on a central database, and wireless Internet is fully available. Reflective textual and visual evidence of all work is uploaded weekly to each student's personal website, which functions as a portfolio. The findings for this paper are drawn from these texts and a series of interviews.

The rationale behind the structure of the semester is to pre-empt the realities of the real world of work in the field of automation. Technicians in this field spend most of their time trying to solve control-related systems problems, and their primary source of information is the Internet, through which they access either technology-specific user data generated by specific industries or other users present in the various user fora. Salomon and Perkins, elaborating on the use of ICTs to facilitate learning, refer to the 'culture' of a learning environment. 'The acquisition of knowledge is ... a matter of the learner's active engagement in ... constructing knowledge out of the raw materials of experience and provided information' (1996: 5). They highlight the fact that 'achievements are jointly constructed in a social system, aided by cultural tools' (1996: 10). There are several 'social systems' implied in working in the manner described during this semester, entailing new or existing relations between the students and their peers, facilitators, industry representatives and the invisible world of fellow users that straddle the globe. These relations and sites of interaction imply a range of 'collaborations' as well as discursive practices. Collectively, these social systems represent, for the student, access to an increasing number of 'repertoires' and 'reservoirs' which not only extend beyond the confines of the academic environment, but are also not necessarily adequately supported by the traditional engineering curriculum which characterises their first two years. More than one student on the programme, on entering the third year, has indicated that 'the first two years feel like a total waste of time'.

For the purpose of the original research project[3], the practices of a particular project group were observed, recorded and analysed over a 3-month period as they designed and manufactured a computer-controlled, air-powered vehicle. Drawing on their weekly reflective time sheets, interviews and observation, a mapping and coding system was developed to describe the sequence and structure (hierarchical and horizontal) of different knowledge types on which the students drew. This mapping (Figure 1) included knowledge forms such as: physics (PHY), mathematics (MAT), mechanics (MEC), logic (LOG), control (CON) and systems (SYS). However, there were constant references to 'non-disciplinary' knowledge, such as social (SOC), experiential and generic practices (GEN). Students refer to both types in varying degrees of abstraction. In order to capture the movement between the different forms and simultaneously demonstrate the level of abstraction, each form of knowledge was mapped against a scale based on Karl Maton's principle of 'semantic gravity'[4], a continuum describing the 'degree to which meaning relates to its context' (2009: 46). The disciplinary and non-disciplinary forms, essentially the distinction between vertical and horizontal discourses, were separated into two planes.

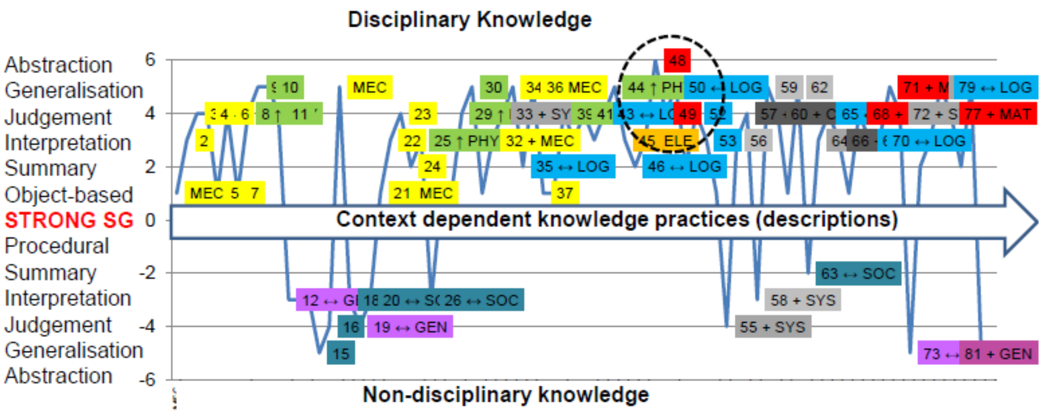

Figure 1. Collective Problem-solving Semantic Wave

This collective problem-solving 'semantic wave' (Figure 1) effectively speaking sequentially summarises the design and manufacturing process of a mechatronic system. The problem starts out as fundamentally structural (mechanical: yellow). The students describe their understanding of and solutions to structural problems in physics terms (green). These are both hierarchical knowledge types. This means, the student has to grasp the underlying principles of a particular problem, and it is expressed in alpha-numeric formulae. With the structure in place, the challenge becomes the logic (blue) entailed in programming the vehicle. Logic, as a horizontal knowledge structure, implies several possible solutions, and in a Mechatronics control system context entails the combination of different programming languages, which encourages a 'trial-and-error' approach. Semiotically, logic in this region would be represented as a schematic flow chart representing sequences of instructions. Problems in the programming logic may either be due to the sequence chosen by the user, syntax of the particular language, or the mathematics (red) in the algorithm underpinning the program. At this stage it becomes difficult to differentiate disciplinary bases and the students increasingly refer to the 'system' and 'control' (grey). Throughout the construction of their controlled electro-mechanical vehicle, there are references to drawing on social (deep blue)

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[3]A full conceptual and methodological analysis is presented in Wolff and Luckett (2013). Figure 1 adapted by permission of Taylor and Francis, http: www.tandfonline.com.

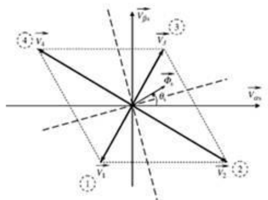
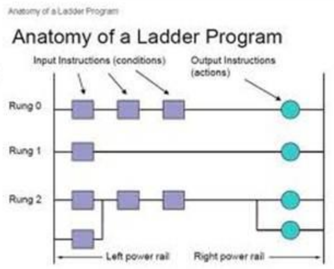
[4]The principle of semantic density was deliberately not applied as the multidisciplinary elements have differing relative density principles.

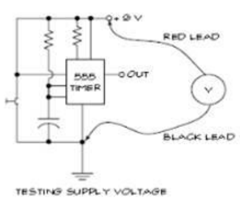
or generic (purple) knowledge practices, as represented in the lower plane. In summary, integrating knowledge in mechatronics engineering is essentially the ability to draw on knowledge from different epistemological areas, at different levels of abstraction depending on particular problem moments, each of which is semiotically and discursively constructed in its own way. The collective semantic wave representing the region suggests a complexity which is not evident in the 'collection' of individual subjects in the curriculum.

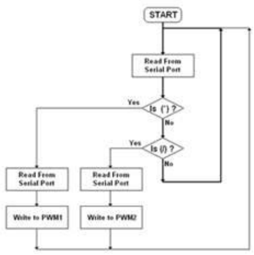
Semiotic and Discursive Practices in a Particular Problem-solving Moment

An example of the implications of this complexity is evident in the group's attempt to control the steering of the vehicle (the dotted circle in Figure 1) using a pulse width modulation (PWM) technique. Essentially PWM is 'a way of digitally encoding analog signal levels [...] [where a] voltage or current source is supplied to the analog load by means of a repeating series of on and off pulses' (Barr 2011). As these signals are related to a change in voltage, the underlying principle is one of physics. However, the rate of change needs to be determined through a mathematical algorithm. Furthermore, in a digital control context such as this project, the focus is on programming the system to respond to the rules of logic. PWM represents a perfect synthesis of the collective underlying disciplinary foundation of Mechatronics. However, when these are taken out of context, such as in isolated subjects in the curriculum, they may be semiotically represented in entirely different ways.

Table 1. Disciplinary Semiotic Domain Characteristics

<table>
<tr><th></th><th>Voltage vectors (physics)</th><th>Algorithm (mathematics)</th><th>Ladder Programming (logic)</th></tr>
<tr><td>CONCEPTUAL (NO SPECIFIC CONTEXT)</td><td>
Abstract mathematical representation of the voltage wave</td><td>$$f(t)=\sum_{k=1}^{\infty} f_{2k-1}\cos(2k-1)t$$
$$f_k=\frac{2}{\pi}\int_0^{\pi/2} f(t)\cos(kt)\,dt.$$
A set of calculation rules</td><td>

Graphical circuit-based logic diagram</td></tr>
<tr><td>CONTEXTUAL (PWM PROBLEM)</td><td>

Schematic circuit diagram</td><td>

Logic of the PWM calculation rules</td><td><pre>sampling_freq = 1000;
 carrying_freq = 50;
 t = 0:1/sampling_freq:10;
 temp =
sawtooth((carrying_freq/2)*2*pi*t);
 carrying_signal =
(temp)/2+range(temp)/4;
 desired_pos_signal = sind(t*360);
 desired_vel_signal =
zeros(size(desired_pos_signal));
 desired_vel_signal(2:end) =
sign(diff(desired_pos_signal));
 PWM =
zeros(size(desired_pos_signal));</pre>
PWM Matlab code</td></tr>
</table>

The first figure in the top row in Table 1 demonstrates voltage as it may be studied in the electrical subject in the curriculum. This representation of voltage vectors is essentially mathematical. In the PWM problem context, however, the students simply have to make a decision about the range between on and off in a circuit, whose representation is a relational schematic diagram (left, bottom). The second figure in the top row is a typical mathematical algorithm. Note how, in the problem context, the 'algorithm' becomes a flow chart, the predominant form of the representation of logic programming. The reason for this is that the control system itself has set algorithms, and the user has to decide on sequence and values. The third figures (both top and bottom) are representations of two of a number of programming languages in typical Mechatronics control systems, the selection and combination of which are entirely dependent on context. Shifting between these fundamentally different representations requires conceptual grasp of the form of representation appropriate to a specific context. Making meaning in this region is predominantly through graphic, schematic and alpha-numeric symbolic representations. In other words, these students (and technicians in the field) spend very little time writing formal academic texts.

The *predominant* form of textual (verbal) engagement in this particular case (amongst many) was via a range of Internet user fora. An analysis of the conversations relevant to the resolution of the PWM problem reveals a range of registers and levels of English proficiency which do not appear to impede the problem-solving process. The conversations are interspersed with lines of computer code, and these become the defining criteria for legitimate participation in the conversation.

Repertoires and Reservoirs

In addition to the forms of disciplinary discursive practice, the students' individual reflective time sheets, when regarded in temporal conjunction with the problem-solving process, reveal that the understanding of the disciplinary elements was facilitated by movement between vertical and horizontal discourses. A particular component was necessary to solve the steering problem. Identifying the component was based on social experience; sourcing it was dependent on Internet expertise; actually purchasing the component meant using discursive practices such as making phone calls, applying budgetary decisions, writing correspondence and negotiating with a range of people. Each of these interactions represents a different type of relationship, and different discursive practices, undertaken by different individuals. Many of these practices are developed through the students' individual horizontal discourse repertoires, sets of 'contextually specific and context dependent' strategies for 'maximising encounters with persons and habitats' (Bernstein 1996: 157-159). The complex context as described in this paper requires a synthesis of repertoires.

Gee's concept of the 'resource precursor trajectory (RPT)' is useful here: 'An RPT for a given semiotic domain is the set of all semiotic domains that contain elements or are associated with affinity groups that facilitate mastering that given domain' (Gee 2002: 30).The RPT for the complex problem solving process described in this paper would entail 'a complex network' (2002: 30) comprising the modalities and 'design grammars' of each of the individual disciplines and regions in the vertical discourse, as well as those characterising the horizontal discourse repertoires. The only space in which this synthesis of repertoires can be facilitated is one in which the entirety of the region is experienced, such as real world practice or a project within a situated learning environment as described. However, the 'content' lecturers responsible for the multidisciplinary curriculum preceding this moment are secure in their disciplinary specialisations in the context of the academy and not necessarily privy to this 'integrated knowledge' space, nor to the particular forms of knowledge and related practices in each other's fields. Each in his/her own right belongs to a particular community which possesses its own reservoir of strategies.

The academic endeavour is intended to enable students to 'understand and produce meanings in the disciplinary semiotic domain that are recognisable to members of that disciplinary affinity group' (Jacobs 2007: 78). The fact that the emerging region currently boasts no defined community presents an opportunity for the reconceptualisation of the nature of academic collaboration required to enable the development of appropriate discursive practices that would characterise a semiotic domain as 'Mechatronics'. Such'collective engagement' (2007: 65) could well shape what an emerging 'regional' affinity group may look like. Furthermore, given the 'reservoir' evident in the invisible community of users present in the ubiquitous technology fora on the Internet, such academic collaboration needs to take this reality into account when addressing 'broader questions of student development' in order to 'locate the intersection where they co-construct a dynamic learning space' (Paretti 2011).

Conclusion

The purpose of this paper has been to illuminate the nature of the epistemological and discursive complexities involved in multidisciplinary engineering practice in the twenty-first century. The analysis demonstrates the complexity not only of integrating two fundamentally different knowledge structure types (hierarchical and horizontal), but also that of the range of associated semiotic and discursive practices. What is increasingly significant is the relationship between the horizontal (every day) and vertical (educational) discourses, as evident in the increasing reliance in technologically-driven emerging regions on knowledge that is freely available outside the academy, and which expresses itself in non-academic discursive form. The purpose of designing curricula and activities to enhance student learning is to enable our graduates to participate in a legitimate and empowered manner in society. If we are to fulfil our obligation to our students, then spaces need to be created in our curricula which facilitate the explicit integration of the different forms of knowledge which will enable complex praxis. Such spaces need to accommodate both the students with their existing repertoires, as well as the 'masters' of specific domains (be they in cyberspace, industry or the academy), and need to acknowledge an emerging and dynamic reservoir of relevant semiotic and discursive practices. This represents a challenge which can only be accomplished by broadening our conceptualisation of collaboration.

References

Bailey McEwan, M. (2009) *Difficulties of Mechanical Engineering Students in Developing Integrated Knowledge for the Cross-Discipline of Mechatronics: A Conceptual Investigation.* Johannesburg: University of the Witwatersrand

Barr, M. (2011) *Introduction to Pulse Width Modulation*. [online] available from <http://www.netrino.com/Embedded-Systems/How-To/PWM-Pulse-Width-Modulation> [29 July 2011]

Bernstein, B. (2000) *Pedagogy, Symbolic Control and Identity: Theory, Research, Critique.* rev. edn. London: Rowman and Littlefield

Bernstein, B. (1996) *Pedagogy, Symbolic Control and Identity: Theory, Research, Critique.* London: Taylor and Francis

Bernstein, B. (1975) *Class, Codes and Control*. Vol. 3. London: Routledge

Bishop, R. H. (ed.). (2002) *The Mechatronics Handbook* [online] available from <http://www.mediafire.com/?ese8srfvtkudtve> [15 December 2010]

Cummins, J. (1996) *Negotiating Identities: Education for Empowerment in a Diverse Society*. California: California Association for Bilingual Education

Gee, J. (2002) 'Learning in Semiotic Domains: A Social and Situated Account'. in *51st Yearbook of the National Reading Conference.* ed. by Schallert, D.L., Fairbanks, C.M., Worthy, J., Maloch, B. and Hoffman, J.V. Oak Creek, WI: National Reading Conference, 23-32

Gee, J. (1996) *Social Linguistics and Literacies: Ideologies in Discourses.* 2nd edn. London: Falmer

Jacobs, C. (2007) 'Towards a Critical Understanding of the Teaching of Discipline-Specific Academic Literacies: Making the Tacit Explicit'. *Journal of Education* (41), 59-81

Maton, K. (2009) 'Cumulative and Segmented Learning: Exploring the Role of Curriculum Structures in Knowledge Building'. *British Journal of Sociology of Education* 30(1), 43-57

MEFSA (2011) *Mechatronics Identity. Mechatronics Education Forum of Southern Africa 2nd General Meeting Minutes*. Unpublished minutes. Cape Town: Mechatronics Education Forum of Southern Africa

Muller, J. (2008) 'Forms of Knowledge and Curriculum Coherence'. [seminar paper] *ESRC Seminar Series. Seminar 2: Epistemology and the Curriculum*, 26-27 June 2008. Bath: University of Bath

Paretti, M. (2011)'Interdisciplinarity as a Lens for Theorizing Language/Content Partnerships'. [online] available from <http://wac.colostate.edu/atd/clil/paretti.cfm> [3 January 2012]

Robinson, K. (2010) *Changing Education Paradigms.*[online] available from <http://www.ted.com/talks/lang/en/ken_robinson_changing_education_paradigms.html>[14 May 2012]

Sadovnik, A. (2001) 'Basil Bernstein (1924-2000)'. *Prospects: the Quarterly Review of Comparative Education* XXXI(4), 687-703

Salomon, G. and Perkins, D. N. (1996) 'Learning in Wonderland: What Computers Really Offer Education'. in *Technology and the Future of Education.* ed. by Kerr, S. Chicago: University of Chicago Press, 111-130

Shooter, S. and McNeil, M. (2002) 'Interdisciplinary Collaborative Learning in Mechatronics at Bucknell University'. *Journal of Engineering Education* 91 (3), 339-344

Wolff, K. and Luckett, K. (2013) 'Integrating Multidisciplinary Engineering Knowledge'. *Teaching in Higher Education* 18(1), 78-92 <http: www.tandfonline.com>

Young, M. and Muller, J. (2007). 'Truth and Truthfulness in the Sociology of Educational Knowledge'. *Theory and Research in Education* 5 (2), 173 – 201